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THE INTERPRETATION OF ARCTIC IMAGERY

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INTRODUCTION

Two aspects of problems encountered in the interpretation of remotely sensed Arctic imagery have been examined. These are the environmental factors leading to degradation of imagery and a review of machine techniques which could aid in the processing of imagery.

Literature surveys in both areas have shown gaps in our knowledge and have resulted in specific suggestions for further work. These are discussed in the paper.

The vastness of the Canadian Arctic, the absence of a large and permanent population and, above all, the absence of sunlight for a very large proportion of the year in the high Arctic, render very difficult searches for parties in distress and the gathering of information for maintenance of control. Remote sensing from aircraft or satellite affords one means for carrying out search, surveillance and reconnaissance in the Arctic. However, widespread and effective use of remote sensing awaits more complete understanding of the potentials and limitations of sensors and sensing.

We have recently completed two literature surveys designed to provide partial answers to the questions, "What sensors can be used and for what proportion of the time?", and secondly, "What techniques using machines would speed up or facilitate the interpretation of sensed data?". The first question is important because the Canadian Forces require an ability to obtain information and carry out searches in virtually all weather and light conditions or in the presence of cloud cover. This implies, in general, a necessity for sensing or imaging in the non-visible portions of the electromagnetic spectrum.

The variety of sensor systems can provide complementary views of the terrain by virtue of diverse spectral sensitivities and imaging geometries. However, the disturbing characteristics of the atmosphere, and the radiometric properties of the terrain differ significantly in visible, infrared, and microwave spectral regions. Each sensor system requires specialized interpretive procedures, and knowledge of its unique characteristics.

ATMOSPHERIC ATTENUATION AND INTERPRETATION

The principal modes of atmospheric attenuation are absorption and scattering. Absorption influences electromagnetic wave propagation very little in the visible and near-visible region (0.3 to 1.0μm) or in the microwave region (beyond 1.35cm). However, in the intervening range, absorption plays a major role. From about 1 to 15μm there are several strong absorption bands, the main "windows" for remote sensing purposes being from 3 to 5μm and 8 to 14μm. There is very little transmission from 15 to 1000μm, and some transmission from 1000μm to 1.35cm.

The effective width of a transmission window is very sensitive to the concentrations of the absorbing species whose presence defines the extremities of the window. This has important implications in the determination of temperature by remote use of infrared radiometry or line scanner techniques. Temperature measurements can be seriously in error when there is a variable amount of water vapour or carbon dioxide between sensor and target, these two absorbers being those which define the limits of the 8 to 14μm window.

The attenuation by atmospheric scattering may be summarized by the statement that microwave radiation penetrates clouds, infrared penetrates haze but not clouds whereas visible radiation penetrates neither. As a general rule of thumb, atmospheric scattering is maximum when the radii of the scatterers are of the same order of magnitude as the wavelength of the propagating radiation. Ideally, one would like to determine the atmospheric conditions during the sensing mission and compute the effects on the sensor. However, because of the magnitude of the computational task and the lack of detailed

knowledge of absorption line shape it is in many cases not practical to calculate exactly the effects of the atmosphere on propagating radiation. Such a computation is further complicated by the constantly changing atmospheric temperature and water vapour profiles. Thus, for the indefinite future, it will be necessary to establish the correction parameters experimentally from a comparison of remotely sensed data with those determined locally by ground truthing, together with corrections for the atmospheric conditions prevailing at the time of measurement.

A number of definite gaps in available information may be cited. In some Arctic locations there is very little information on such common factors as temperature, precipitation, wind, solar and long wave radiation (inward and outward radiation), type and proportion of cloud cover, fog, visibility, concentrations of ozone and carbon dioxide, how the air temperature varies from year to year with changes in the incoming radiation, the relative contributions to the atmospheric moisture content by evaporation from open leads and by sublimation of snow and on the formation and persistence of temperature inversions over the ice cap. Insufficient experimental work has been carried out on transmission, emission, and backscatter of infrared radiation under cold weather conditions, including the effects of winter fog, snow and ice crystals. In fact, even in the temperate regions, very little has been done to measure the backscattering coefficient in the infrared. Further study of rapid variations in the refractive index of water droplets with wavelength in the 8 to 14μm region is required to provide an understanding of the transmission of infrared, and particularly laser radiation through aerosols, and for the development of a model for atmospheric scattering and absorption under Arctic conditions.

The reflection characteristics of snow and ice under a variety of weathering conditions have not been sufficiently investigated nor have there been adequate determinations of the thermal contrast one may expect between a target and its background after radiation has traversed a given path through the atmosphere under given meteorological conditions. Most of the transmission studies have been on the attenuation of a beam of infrared radiation under these conditions rather than on target contrast. In relation to this, little quantitative information exists on the reduction of surface contrast with surface wind speed and the rate of dissipation of a given temperature gradient at a given ambient temperature under various wind conditions and the pronounced variations in spectral signatures which result from both diurnal and seasonal changes. Finally, data are lacking on the amount of attenuation one would expect for an electromagnetic beam, at microwave and infrared frequencies, propagating through falling and blowing snow.

PATTERN RECOGNITION

The other factors of importance, in Arctic reconnaissance, namely the enormous area to be sensed and the sparsity of search support from ground personnel, must result in the accumulation of far more sensed data and imagery than can possibly be adequately or usefully examined by a limited number of trained interpreters. Thus, there is a requirement for methods of discarding most of the redundant information so that observers can derive information while it is still useful, for example, in time to make it worthwhile to send in rescue parties following location, on imagery, of a downed aircraft.

The human photointerpreter is the vital key to all aerial reconnaissance tasks at the present time and will be for the foreseeable future. Although many advances are evident in machine data processing, the human interpreter has not been superseded. The interpreter employs trial and error, intuition, logical deduction, and a wealth of background experience and knowledge in the achievement of his task. Interpretation is based, in part, on features not resident in the picture, and also upon the viewer's purpose. Many pattern recognition studies of relevance to aerial reconnaissance problems have been reported in the literature, and a conclusion typical of most of them is that "the method shows great promise". However, an operationally workable system remains to be demonstrated. Satisfactory procedures have been developed only for simplified restricted problems, and suffer from many limitations. It is evident that the significant features have not been clearly defined, the important relationships are poorly understood, and the available remote sensing data base is inadequate.

One of the major limitations of automatic spatial pattern recognition is sensor capability. This is particularly true in the Canadian Arctic where winter darkness, low sun angle and cloud cover preclude good photography during much of the year. Thus it is necessary to rely on the infrared line scanner, sideways looking airborne radar and low light level T.V., all of which provide

less spatial resolution than photographs. Furthermore, since some of these sensors image in normally non-visible portions of the electromagnetic spectrum, intensive efforts to provide acceptable ground truth are necessary.

Ideally, a man/machine system concept should be adopted in which the pattern recognition and data processing functions are performed by the system element which is best suited to the task. The human becomes the pattern recognizer. The machine is the data processor, which performs all data handling and image processing tasks except direct pattern recognition. The machine should provide preprocessing of all available support data which the interpreter demands, and should display it in the most easily assimilated and interpreted form. Preprocessing attempts to modify the transfer function of the data retrieval system to compensate for the effects of system noise, distortion, blurring, etc., and for environmental effects of atmosphere, illumination, terrain structures, etc. Non-restorative preprocessing is also employed to remove irrelevant and redundant information or to enhance edges, contours, and gradients by a "non-realistic" transformation. Preprocessing is not generally selective against uninteresting objects and often generates artifacts which require perceptive interpretation. Conversely, all data derived from the imagery by the human should be input to the computer through the on-line hardware which he operates in the performance of his interpretive task. Other machine assists could be the storage and retrieval of information, semi-automatic entry of mission flight data, mensuration and computation (of object size, height, ground position, distance between objects, etc.), rectification, reorientation, plotting, and compilation and print-out of formatted reports.

The central and most difficult problem in pattern recognition is that of feature extraction from a background of irrelevant detail. This process must precede recognition. An ideal feature extraction would be independent of noise and limited variations in object size, orientation, contrast and topological deformation. In the past, feature extraction systems have had most success in the field of character recognition, limited success in target acquisition systems and less success in other areas. There is currently no unique feature selection technique applicable to all pattern recognition problems, and no general theory to guide the choice of relevant features. These features are generally tested for effectiveness in terms of their contribution to the probability of correct recognition or in terms of a specified selection criterion, the choice of which may be empirical.

Gestalt approaches to pattern recognition treat patterns as unified organized entities, and assume that analysis into characteristic elemental features destroys the pattern. Mask matching techniques and its variants, which include optical matched filtering, fall into this class, and are highly sensitive to object size, orientation, and shape, and also to translation of the correlation filter. Even though techniques are available to circumvent scale and orientation sensitivity, mask matching offers little prospect of direct utility to pattern recognition problems in Arctic reconnaissance because the interesting patterns lack the required uniformity.

Time represents a very powerful and valuable dimension in which to discriminate and identify patterns. Change detection is very difficult to automate, however, because time-displaced imagery usually cannot be placed in registration, and point-by-point comparison cannot be employed. Sophisticated pattern recognition techniques are required to effect a spatial correlation of equivalent image elements in the two images before detailed changed detection can be implemented.

There is no simple solution to any of the Arctic reconnaissance and surveillance problems using pattern recognition, particularly in areas such as the detection of men in distress, small-scale camps and human activities, etc. However, deliberate attempts to be conspicuous to a known pattern recognition system by parties in distress greatly enhance their chances of detection.

We recommend that pattern recognition studies be concentrated, at least for the present, in the areas of preprocessing or image enhancement, spectral discrimination of targets, discrete target detection and identification, and change detection.

In conclusion, we make a plea for an improvement in one aspect of the interpretation problem that does not form part of our review. A very important component of remote sensing data is accurate positional information, effectively annotated by computer or otherwise to the data. Data or imagery often lose much of their usefulness through lack of an accurate navigational fix at the time of data acquisition. It must be

less spatial resolution than photographs. Furthermore, since some of these sensors image in normally non-visible portions of the electromagnetic spectrum, interactive efforts to provide acceptable ground truth are necessary.

Ideally, a man-machine system concept should be adopted in which the pattern recognition and data processing functions are performed by the system element which is best suited to the task. The human becomes the pattern recognizer. The machine is the data processor, which performs all data handling and image processing tasks except direct pattern recognition. The machine should provide preprocessing of all available support data which the interpreter demands, and should display it in the most easily assimilated and interpreted form. Preprocessing attempts to modify the transfer function of the data retrieval system to compensate for the effects of system noise, distortion, blurring, etc., and for environmental effects of atmosphere, illumination, terrain attributes, etc. Non-restorative preprocessing is also employed to remove irrelevant and redundant information or to enhance edges, contours, and gradients by a "non-realistic" transformation. Preprocessing is not generally selective against uninteresting objects and often generates artifacts which require perceptive interpretation. Conversely, all data derived from the imagery by the human should be input to the computer through the on-line hardware which he operates in the performance of his interpretation task. Other machine duties would be the storage and retrieval of information, alpha-numeric entry of mission flight data, measurements and computations for object size, height, ground position, distance between objects, etc.), rectification, restitution, plotting, and compilation and print-out of interpretation reports.

The central and most difficult problem in pattern recognition is that of feature extraction from a background of irrelevant detail. This process must precede recognition. An ideal feature extraction should be independent of noise and limited variations in object size, orientation, contrast and topological deformation. In the past, feature extraction systems have had most success in the field of character recognition, limited success in target acquisition systems and less success in other areas. There is currently no unique feature selection technique applicable to all pattern recognition problems, and no general theory to guide the choice of relevant features. These

features may prove to reveal the differences in terms of their applicability to the probability of correct classification or in terms of a particular criterion criteria, the choice of which may be arbitrary.

Overall that those of military intelligence those problems we consider important today and leave the investigation, interpretation, elemental features observing that pattern. That matching techniques and its variants, which include spatial matched filtering, fall into this class, and are highly sensitive to object size, orientation, and shape, and also to transformation of the perspective views. Even though techniques are available to alignment scale and orientation shift invariance, most matching techniques suffer problems of direct utility in pattern recognition problems in which differences between and interesting patterns lack the required uniformity.

Time represents a very powerful and valuable dimension in which to discriminate and identify patterns. Change detection is very difficult to automate, however, since two time-displaced imagery usually cannot be aligned in registration, and point-by-point comparisons cannot be employed. Sophisticated pattern recognition techniques are required to extract a spatial correlation of equivalent image elements in the two images before an actual changed detection can be implemented.

There is no simple solution to any of the Air Force reconnaissance and surveillance problems using pattern recognition, particularly in areas such as the detection of damage to aircraft, specifically small and human activities, etc. However, sufficient attempts to be made towards as a whole pattern recognition system to perform so also to greatly enhance their chances of acceptance.

We recommend that patterns or machine vision be concentrated, at least for the present, in the areas of preprocessing of image enhancement, spectral discrimination of targets, obscure target detection and identification, and change detection.

In conclusion, we make a plea for an improvement in one aspect of the interpretation problem that does not form part of our survey. A very important component of remote sensing data is the extra additional information, collateral, contained in computer or otherwise in the data. This ... imagery often goes back on digital tapes through lack of an accurate and unambiguous tie at the time of data acquisition. It must be

recognized that navigational equipment employed on reconnaissance missions is often inadequate to provide the required accuracy.

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